

PB-217 809

PRESENT TECHNOLOGY OF SLUDGE DEWATERING

James E. Smith, Jr.

**Federal Water Quality Administration
Cincinnati, Ohio**

October 1970

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Federal Water Quality Administration
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ABSTRACT

A review of problems confronted in disposing sludges from water purification and municipal wastewater treatment plants is presented. The quantities and characteristics of these sludges that must be dealt with are enumerated. Waste sludges originating from the activated sludge and tertiary treatment processes together with alum sludges are typically high in moisture and gelatinous in nature and are shown to present the greatest challenge in dewatering.

Each of a variety of biological, chemical and physical treatment alternatives is discussed. Emphasis is placed on the present and recently completed in-house research of the Ultimate Disposal Research Program, Advanced Waste Treatment Research Laboratory, Federal Water Quality Administration. This includes the optimization of the aerobic stabilization process, the use of organic polymers and various inorganic additives including iron and aluminum salts, and sludge incinerator ash on sludge filtration and thickening. For some treatment plants sludge incinerator ash is an economical way of increasing the filter yield.

Freezing of aluminum hydroxide sludges was demonstrated as an excellent means of concentrating and dewatering sludge when it could be done naturally in a cold climate, but artificial freezing is economically prohibitive. Pasteurization is discussed as a means for reducing the pathogens present in sludge.

Land spreading, strip mine reclamation, landfill, ocean disposal,
and pipeline transport are discussed. The present economics of some
processes are noted.

PRESENT TECHNOLOGY OF SLUDGE DEWATERING *

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INTRODUCTION

Solids removed in the processing of waters for human consumption, industrial usage, or in the case of wastewaters, for discharge to a receiving stream, present a disposal problem which must be considered in the design of sanitary facilities. The disposal of sludges from wastewater treatment will today account for up to 50% of the total treatment cost.¹

The purpose of this presentation is to discuss some alternative methods for treatment and ultimate disposal of sludges. Particular attention is given to the present and recently completed in-house research in the Ultimate Disposal Research Program at the Robert A. Taft Water Research Center, and new developments in the technology.

Sludge can be defined as the settleable solids that are naturally present in water and wastewater, or that are formed from nonsettleable matter by chemical coagulation and precipitation and by biological flocculation and precipitation. Sludge is a semi-liquid waste which flows, can be pumped, exhibits hindered settling characteristics, and is usually brown to black in appearance. Odors may or may not be present.

Tighter effluent criteria and the resultant construction of additional secondary facilities, increasing land scarcity, and population pressure have combined to make sludge disposal more difficult and expensive than ever before. While no "breakthroughs" in sludge disposal technology have occurred, new ideas for the treatment and disposal of sludges have been proposed or put into use in recent years. The results of this increased activity should be improved technology and lower costs for average sludge disposal.

* For presentation at 64th Annual Meeting, American Society of Sanitary Engineering, Atlanta, Ga., Oct. 19, 1970.

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ORIGIN OF SLUDGE

Sludges originate from three principal locations--industry, water treatment plants, and wastewater treatment plants. Processes for treatment of wastewater are commonly classified as primary, secondary, and tertiary. In each of these processes, sludges are produced. The three processes are illustrated in the flow diagram of Figure 1.

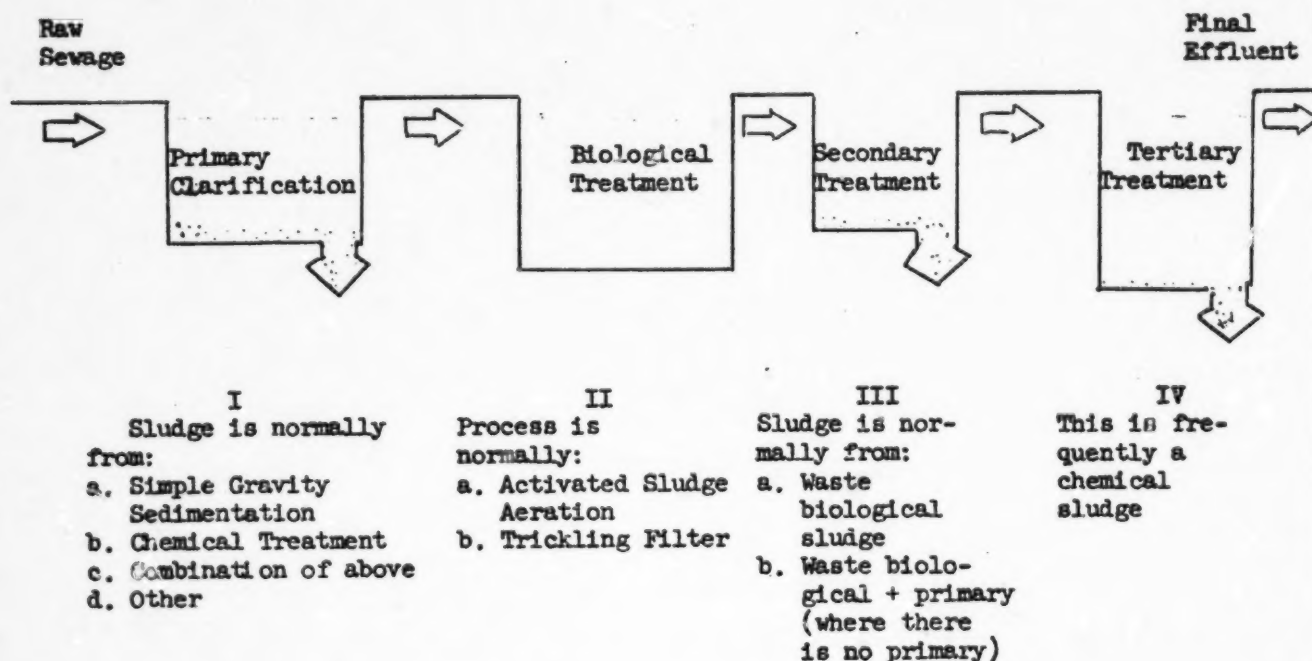


FIGURE 1. SOURCES OF WASTEWATER TREATMENT SLUDGES

The quantities of sludge produced in the treatment of wastewater by simple gravity sedimentation, chemical treatment and biological processes are shown in Table 1.

TABLE 1. TYPICAL QUANTITIES OF SLUDGE PRODUCED IN
WASTEWATER TREATMENT PROCESSES

<u>Treatment</u>	<u>Keefe²</u>	<u>Imhoff & Fair³</u>	<u>Babbitt⁴</u>	<u>M&E⁵</u>
Plain Sedimentation	2,950	3,530	2,440	3,000
T F Humus	745	530	750	700
Chem. Precipitation	5,120	5,100	5,250	5,100
Activated Sludge	19,400	14,600	18,700	19,400

(Given as gallons/million gallons sewage treated)

The table shows that the least amount of sludge is produced by either simple sedimentation alone or in conjunction with a trickling filter. On the other hand, if chemical addition is practiced or the activated sludge process is included in the processing sequence, large additional quantities of sludge must be handled, necessitating larger facilities.

SLUDGE CHARACTERISTICS

The moisture quantities of some typical wastewater treatment plant sludges are shown in Table 2. This table shows that the water content of all the sludges shown is high. Obviously additional treatment is needed before incineration can be considered. In the case of the primary chemically precipitated and digested sludges, we see that 10 to 20 pounds of water are present for every pound of sludge solids. On the other hand, with the activated sludge and high rate trickling filter sludges we have as much as 50 pounds of water for every pound of sludge solids, making disposal much more difficult. Table 3 illustrates once more that activated sludge has a high moisture content. As expected from its low solids content,

TABLE 2
PERCENTAGE MOISTURE CONTENT OF
SOME TYPICAL SLUDGES

<u>Treatment</u>	<u>% Moisture</u>
a) Primary Sedimentation	95
b) Chemical Precipitation	93
c) Trickling Filters	
1. Humus - Low Rate	93
2. Humus - High Rate	97
d) Activated Sludge	98 - 99
e) Well Digested Sludge	
1. Primary Treatment	85 - 90
2. Activated Sludge	90 - 94

TABLE 3

CHARACTERISTICS AND QUANTITIES OF SLUDGES⁶

<u>Treatment</u>	<u>%SS Rem</u>	<u>#/d/mg removed</u>	<u>Vm %</u>	<u>Sp Gr S/Solids</u>	<u>Moist %</u>	<u>Liquid Sp Gr</u>	<u>Sludge wt/gal</u>	<u>g/mg</u>
Plain Sed.	60	1,020	65	1.33	95	1.013	8.45	2,410
Tr F Humus	30	510	45	1.52	93	1.025	8.55	852
Act. Sludge (excess)	42	714	65	1.33	98.5	1.005	8.36	18,700
Imhoff Tank Dig.	60	1,020	50	1.47	90	1.033	8.62	827

%SS Rem = Suspended Solids Removal

#/d/mg = Pounds/day/million gallons

Vm % = Percentage of volatile materials removed

Sp Gr = Specific Gravity

its density is only slightly greater than the density of water. Further in Table 3 we see that up to 8 times as much activated sludge is produced for every million gallons of wastewater treated as compared with primary treatment.

Just as important as the amount of water in the sludge is the ease with which the sludge solids and water can be separated. Unfortunately, the sludges with the highest water content--the biological sludges--are the hardest to dewater. Unless treated in some way, they cannot be economically dewatered.

SLUDGE DISPOSAL ALTERNATIVES

The existence of a disposal problem is apparent. In selecting a disposal process, the pollution potential, aesthetics, and economics of the process must be considered. There are biological, chemical, and physical methods available to us, as shown in Figure 2.

BIOLOGICAL PROCESSES

In the bacterial line we have: 1) Aerobic stabilization; 2) Anaerobic digestion; and 3) Composting.

AEROBIC STABILIZATION

Aerobic stabilization describes the separate aeration of waste primary and/or of secondary sludge. This process is usually designed for a long retention time of 15 to 30 days. The biological steps occurring include: 1) the direct oxidation of any biodegradable matter by the biologically active mass of organisms; and 2) oxidation of microbial cellular material, endogenous respiration.⁷ This process has aroused much interest where a demand for small treatment plants exists. Aerobic stabilization is simpler to operate than anaerobic digestion and requires

WHICH ONE IS THE BEST???

Chemical
Treatment

inorganic conditioners
organic conditioners
recovery fertilizer

Biological
Treatment

aerobic
anaerobic
enzymes
composting

Physical
Treatment

freezing
heat
filtration
thickening

Ultimate Disposal

land spreading
strip mines
ocean disposal
incineration
land fill
dry fertilizer

Tons and Tons of Sludge

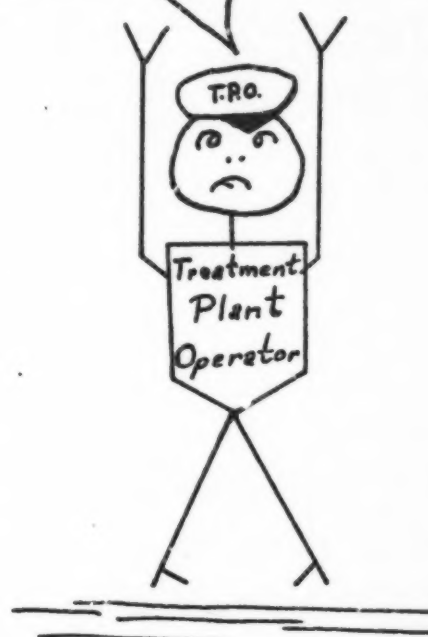


FIG. 2

DEWATERING ALTERNATIVES

a smaller capital expenditure. It is also aesthetically more acceptable in that the resultant sludge is suitable for disposal by land spreading or landfill. Other advantages to the aerobic stabilization process include: 1) reduction in pathogenic microorganisms; 2) grease removal; and 3) a supernatant which requires little treatment. Important parameters in this process are air requirements, time of aeration, sludge age, and filterability, settleability, and drainability of the product. The disadvantages include high operating costs and unclear design criteria. This process is being extensively used in the state of Pennsylvania; much more information must be gained for accurate evaluation of aerobic stabilization.

Significant reductions in volatile solids, grease, and pathogenic microorganisms were achieved in our past studies performed with waste activated sludge from the Colerain Heights Sewage Treatment Plant of the Metropolitan Sanitary District of Cincinnati. Recently, the use of pure oxygen for aerobic stabilization was studied by the Ultimate Disposal Research Program in Cincinnati to determine if oxygen offers any advantages over the use of air. Two aerobic stabilization reactors, each 40 gallons in capacity were operated for 15 days, one with air addition and the other with pure oxygen gas addition. The sludge was obtained from the Colerain Heights Plant. The dissolved oxygen level in the pure oxygen reactor was kept about 5 mg/l higher than that in the air unit which was about 2 mg/l.

Table 4 shows reductions in the various parameters with aerobic stabilization.

TABLE 4

REDUCTION IN SLUDGE PARAMETERS WITH 15-DAY AEROBIC STABILIZATION PERIOD

Parameter	Air (%)	Oxygen (%)
Volatile Suspended Solids	40	30
Chemical Oxygen Demand	39	21
Grease	62	65
Total Solids	26	11
Organic Nitrogen	28	little
Ammonia	100	little

Sludge filterability by rotary vacuum filter and settleability were not improved with aerobic stabilization. The air unit showed a very large increase in acidity and decrease in alkalinity. The nitrate concentrations in this unit increased at an approximate rate of 12 mg/l per day, reaching a final value of 190 mg/l. The nitrates increased at a rate of 9 mg/l per day in the oxygen unit and a final value of 145 mg/l was observed. Pathogen analysis revealed that the air unit was more effective than the oxygen unit in reducing indicator organisms and total aerobic bacteria.

ANAEROBIC DIGESTION

Anaerobic digestion is the biological conversion of organic matter in the absence of molecular oxygen to simple compounds. End products of the conversion are chiefly methane and carbon dioxide.⁸ The methane generated has frequently been used for heating and to run generators. Control of the digesters is often difficult because of the sensitivity of

microorganisms to toxicity, and capital costs are high. The supernatant presents a treatment problem, since it is usually high in BOD and solids.

COMPOSTING

Composting has received attention because of its relative versatility in solid waste treatment. Organic, industrial, agricultural as well as domestic sludges have been examined. The degree of interest in composting in this country, as well as abroad, is dwindling for economic reasons.⁹ The usual reason for failure of composting plants is the inability to develop a market for the compost.

CHEMICAL METHODS

Numerous methods for chemically treating and conditioning sludges to assure satisfactory dewatering are being explored to assess their effects in the preparation of sludge for filtration, centrifugation, flotation, and gravity thickening. Inorganic chemicals widely used in the past include: ferric chloride, copperas (FeSO_4), chlorinated copperas ($\text{Fe}_2(\text{SO}_4)_3$), aluminum chlorohydrate, and alum. Use of polyelectrolytes, a relatively new and rapid chemical development, is growing in popularity for the conditioning of sludge. Required dosages of chemicals and polyelectrolytes are thought to be a function of solids content, alkalinity, and other factors.

The Ultimate Disposal Research Program recently made a study into the chemical conditioning of activated sludge for vacuum filtration. Five inorganic and three organic sludge conditioners were evaluated using the Buchner funnel¹⁰ and/or filter leaf test¹¹ to determine their effect on the vacuum filtration of sludge. The Buchner Funnel Test gives a measure

of a sludge's resistance to filtration, whereas the filter leaf test gives the expected sludge production rate on a rotary vacuum filter in pounds of sludge solids per square foot per hour. Surprisingly, the most effective inorganic conditioner was found to be sludge incinerator ash. Sludge ash is available on site, free of charge, if the filtered sludge is incinerated. At all levels of addition of ash an improvement in filterability was noted. An almost linear relationship existed between the filter yield and the quantity of ash added. At a maximum dosage of 5 parts ash to one part activated sludge, filterability was improved by a factor of 4.

The use of polyelectrolytes to improve vacuum filtration was studied in another series of experiments. A total of 20 different polyelectrolyte sludge conditioners were tested. The following conclusions were drawn from this work. Rohm and Haas' C-7* gave the best filtration improvement with a fourfold increase in the filter yield and the lowest cake moisture, at a cost of \$20/ton dry solids. Hercules 814 gave the next best filtration improvement, but the cake had a very high moisture content and the cost was \$26.25 per ton dry solids. Calgon's 287 gave a good filtration improvement but the cake moisture was high; however, the cost was \$8/ton. From an economic standpoint, probably Calgon's 266 was optimal, since a filtration improvement of 2.60-fold with a moisture of 5 lbs. of water per pound of solids resulted, at a cost of about \$7/ton dry solids. Additional studies are being considered. All work using polyelectrolytes was performed with waste activated sludge obtained from the Mill Creek Sewage Treatment Works in Cincinnati.

* Mention of commercial products does not imply endorsement by the U. S. Government.

SLUDGE CONDITIONING WITH INCINERATOR ASH

A later study was made by the Ultimate Disposal Program to determine the effect of sludge incinerator ash on the rotary vacuum filtration of raw primary, digested, activated and trickling filter sludges.

The sludges studied were predominantly from plants located within the Metropolitan Sanitary District of Cincinnati. Ash was usually obtained from Cincinnati's Mill Creek Sewage Works' sludge incinerator. Sludges and ashes were included from other localities in the country, however, to make the results of this work more widely applicable. In all instances the corrected filter yield was calculated and the test results reported as pounds of actual sludge solids per square foot per hour.

The conclusions from this investigation may be stated as follows.

- 1) In almost every case the filter yield was noted to increase with the addition of incinerator ash. The amount of increase depended on the level of ash addition, the percent solids in the study sludge, the source of sludge and, to a lesser extent, the source of ash.
- 2) The primary and digested sludges showed up to a three-fold increase in filter yield when up to six parts of ash were added for every part of sludge solids present.
- 3) Activated sludge showed on an average a five-fold increase in filter yield when four parts or more of ash were added for each part of sludge solids present.
- 4) Trickling filter sludge showed a filter yield increase of up to forty fold when as much as nine parts of ash were added for every part of sludge solids present.
- 5) The resulting filter cake moisture content based on original sludge solids was found to increase slightly with the quantity of ash used to condition the sludge.
- 6) Filtrates resulting from the filtration of ash conditioned sludge were significantly lower in suspended solids, TOC and total phosphorus than filtrates from filtration of unconditioned sludge.

SLUDGE STABILIZATION BY LIME AND SULFUR DIOXIDE ADDITION

A revolutionary and, from our point of view, economically promising idea was stabilizing sludge with lime or sulfur dioxide in preference to biological digestion. This treatment would be used prior to land spreading of sludge or placing it on drying beds. We performed basic studies to determine the effect of elevating the pH of a sludge with lime to 11.0 and maintaining it there for a period of 24 hours. Similarly, the effect on sludge by adding small quantities of sulfur dioxide for the purpose of stabilizing was evaluated. Both primary and activated sludges were studied. Success was expected with these processes because the odor-producing, and probably the pathogenic organisms would be killed. In the case of lime at pH 11, both the elevated pH and the production of ammonia in the sludge are responsible for destruction of the organisms, while in the other instance the sulfur dioxide itself is toxic to the organisms. In all instances, obnoxious odors and colors were almost instantly eliminated by treatment either with lime or sulfur dioxide.

PRODUCT RECOVERY

The recovery of valuable products from sludge, and its use as an animal-diet supplement have been investigated.^{12,13,14} The problems with all such methods are the costs of recovery and the finding of a market. In some areas, such as Milwaukee, dried activated sludge is bagged and sold as a fertilizer. Milwaukee's success is attributed to a substantial selling effort, an activity which most municipal authorities are unwilling to undertake.

PHYSICAL PROCESSES

FREEZING

Several approaches are being taken with physical processes. The freezing of water treatment plant sludges is practiced in Europe, but is not beyond the pilot stage in the United States.^{15,16} Both artificial and natural freezing are employed. Freezing is found to greatly enhance the ability of the sludge to be dewatered. Under present conditions, however, natural freezing with its limitations is being looked upon with much more favor than are the artificial processes because of their poor economics.

Natural secondary effluents obtained from local treatment plants and synthetic effluents were employed in this study. Natural freezing of the sludges generated by the addition of alum to the effluents was investigated by the Ultimate Disposal Research Program as a process for improving their dewaterability.¹⁷ Snow cover, the available environment, completeness of freezing, sludge depth, method of application, and organic content were found to be important variables. Thickening of the sludge due to natural subsidence and the effect of different phosphorus levels were also studied. Sludge after complete freezing was found, upon thawing, to rapidly settle and filter with a magnitude of improvement of 3 to 4 times. Supernatant quality was relatively good. In actual practice, a large surface-to-volume ratio was found desirable along with provision for keeping the surface free of snow. Since complete freezing is essential, the application of thin layers was found to be a good approach. Studies were conducted both at Ely, Minnesota and Cincinnati, Ohio.

HEAT

Drying Beds

Heat as a method of physically treating sludge is employed in a number of processes. One of the more common methods of handling sludge is to pump it out onto sand drying beds, where the excess water is removed by percolation and evaporation. The sludge has usually been anaerobically digested before being spread on beds. Important factors are depth of applied solids, concentration, and media used. As you can see, this method requires considerable land area. The finished sludge usually contains 50-60% water.

Artificial Drying

Heat drying of sludge is practiced only if the sludge is to be used as a fertilizer. A rotary kiln and flash drier are commonly used. Sludge moisture is reduced to about 10%. The chief advantage is the death of pathogens.

Pasteurization

In some instances, sludge is pasteurized for health purposes prior to spreading on land. Pasteurization has become popular in Europe as a pretreatment of waste digested sludge for land spreading.¹⁸ There have remained, however, questions as to the actual health benefits gained by pasteurizing sludge. In our laboratory raw sludge, digested sludge and activated sludges were pasteurized by rapidly heating them to 70°C. and then holding them at this temperature for 30 minutes. Biological analyses indicated that the pathogens were killed by the pasteurization process in all cases and no pathogens remained after pasteurization.

Pathogens were present in all sludges not treated with heat. Greenhouse pot tests with corn planted in sand and treated with raw, waste activated and digested sludge respectively, pasteurized and unpasteurized, were compared. Pasteurization affected neither germination or growth, except for the digested sludge. Digested sludge inhibited germination but when pasteurized digested sludge was applied the corn germinated and grew normally.

Zimmerman Process

The Zimmerman Process also involves heat. In this process, the organic matter in sludge is oxidized by contacting air and sludge in a reaction vessel under sufficient temperature and pressure. Operating conditions range from 500° to 700°F. and 1200 to 1800 psig. This process may not require external power to sustain combustion once it is started, if the solids content is sufficiently high. Up to 90% of the organic matter can be removed.¹⁹ A large problem is treatment of the supernatant produced by the process.

Porteous Process

The Porteous Process involves the pressure cooking of sludge at 370°F. The sludge is hydrolyzed, living cells and spores are killed, and filtration is made easier.²⁰ However, soluble nutrients and BOD are released into the supernatant and liquor. A low pressure Zimmerman process is available which produces an effect very similar to simple heat treatment.

SLUDGE DEWATERING

Sludge thickening or concentrating can be done by a number of methods. These include vacuum filtration, pressure filtration, centrifugation, gravity, flotation, roto plug, and vibrating screens.

VACUUM FILTRATION

Vacuum filtration is practiced on raw sludge, digested sludge, chemical sludges, and activated sludge. Typically, the filter consists of a cylindrical revolving drum 4 to 8 feet in diameter which is partially submerged in a tank of sludge. The drum is divided into sections which may be placed under positive or negative pressure. As the drum revolves, sludge is picked up by the vacuum. Excess water is sucked into the center of the drum, leaving a sludge cake on the filter cloth. The sludge is removed from the filter by low pressure air and a shear plate. While the moisture content of the raw sludge may range between 90 and 97%, the moisture content of the sludge cake will range between 70 and 80%. Filter presses are widely used in Europe, and improvements on them have been made in recent years. The solids content of the product is about 40 to 60%.²¹

CENTRIFUGATION

Centrifugation is a method for the concentration of sludge.

All centrifuges are sedimentation type units.

There are three basic types of units. They are the disc, conveyor, and basket centrifuges. The disc unit typically operates around 6500 G-forces and can be used for activated and chemical sludges once they have been screened. The conveyor or scroll unit, which is the most popular in wastewater treatment, has adjustable weirs for the bowl or pond depth. It is not recommended for alum or activated sludge but is good for raw and digested sludge. It operates at approximately 3000 G-forces. The basket centrifuge has a vertical bowl and operates between 1300 and 1600 G's. Solids are discharged by a scraper and tube coming down into the bowl. This unit is good for activated and

chemical sludges.

In the conveyor centrifuge, sludge slurry enters a rotating bowl through a stationary feed pipe extending into the hollow shaft of the rotating screw conveyor and is then distributed through ports into a pool within the rotating bowl. It is possible to vary the depth of this liquid pool. While the liquid is flowing through the cylindrical section towards the overflow devices, finer and finer solids are settled centrifugally to the rotating bowl wall. The conveyor pushes these solids to the conical section, where the water is pushed out. This water is the centrate.²²

The basket and disc centrifuges are now beginning to find more of a place in the wastewater treatment industry as the use of each piece of equipment is more clearly defined.

FLotation

Flotation is another method for concentrating solids. Rising gas bubbles are used to increase the buoyance of solid particles. Five methods have been suggested for this. They are: 1) Dispersed air flotation; 2) Dissolved air-pressure flotation; 3) Dissolved air-vacuum flotation; 4) Biological flotation; and 5) Electrolytic gas flotation. Dissolved air-pressure flotation is the most popular and is used in the thickening of activated sludge. It has been thickened to 4% with this method.²³

OTHER DEWATERING TECHNIQUES

Gravity sludge thickening, using clarifiers containing a mechanism with pickets, has been successful.²⁴

Other methods for concentrating sludge include the "Roto Plug" device and vibrating screens.

ULTIMATE DISPOSAL

LAGOONING

Lagooning or landfill is frequently employed as a means of ultimate disposal. Lagoons can be used as anaerobic digesters, being mindful of the aesthetic problems; as an evaporation pond, where the sludge is allowed to dry and then be removed; or as permanent lagoons or landfills where an area is filled to a desired depth with sludge and allowed to dry. Area requirements and management are important.

LAND SPREADING

Digested and aerobically stabilized sludge may be used as fertilizer or soil supplement. Raw sludge presents health and nuisance problems. Transportation costs must be considered.

Fertilizer Value of Bio-Oxidation Sludge

Nitrogen	1-5%
Phosphate	1-3%
Potash	0.1 - 0.3%

Anaerobic digestion will reduce these values 40-50%.

INCINERATION

Incineration in either a multiple hearth or a fluidized bed furnace is a method of ultimate disposal in which the sludge, either raw or digested, is burned and reduced to combustion gases or ash. Multiple hearth furnaces range in capacity from 200 to 8,000 #/hr. of dried sludge, and operate at

2,500°F. The Multiple Hearth Furnace consists of a refractory-lined circular steel shell with refractory hearths, which lie one above the other. Sludge is fed through the furnace roof by a screw feeder or belt and flopgate. A rotating air-cooled central shaft with air-cooled rabble arms and teeth plows the sludge across the top hearth to drop holes. It falls to the next hearth and then the next until ash discharges at the bottom.

In a fluidized bed furnace, the mechanically dewatered sludge is fed into a fluidized sand bed that is supported by air at 3.5 to 5.0 psi. Normally, sludge solids are degrittied before dewatering to prevent equipment wear and to obtain a sludge with the highest possible volatile content. The fluid bed reactor is a single chamber unit in which moisture evaporation and combustion of organics takes place simultaneously under oxidizing conditions at 1,400 to 1,500°F.²⁸

UNIQUE METHODS FOR HANDLING SLUDGES

It is necessary in an area such as ours which is responsible for a major cost portion of treating waste water to finance a few projects which seemingly are far out in the hope that by chance they will yield a result which would greatly cut the cost of sludge handling. Some of the projects which fall in this category and which are supported by the FWQA and monitored by the Ultimate Disposal Research Program are listed below together with their level of financing.

level of financing.

<u>Company Receiving Grant or Contract</u>	<u>Project Financed</u>	<u>Level of Financing</u>
Rocketdyne, Canoga Park, California	Electro-osmosis as a Technique for Sewage Sludge Dewatering	\$ 79,966
Clemson University Clemson, South Carolina	Fermentation of Sewage Sludges to Useful Products	\$ 89,000
Aerojet-General Corp. El-Monte, California	Biological Methods of Sludge Dewatering (Enzymes)	\$ 93,000

OTHER TECHNIQUES

FWQA studies are currently underway on strip mine filling with sludge, spreading of sludge on land, acceptability of sludge by farmers.^{25,26,27}

Coastal cities often dispose of raw sludge through release into the ocean directly from outfalls. To date, it has been impossible to make a single set of standards, but we do know that some coastal areas have been polluted.

USUAL SLUDGE TREATMENT PROCESS COMBINATIONS

The most common process combinations employed in the handling and disposal of sludge can be listed as follows:

1. At the sewage treatment plant--anaerobic digestion followed by sand bed dewatering. For many treatment plants, this is the least costly method.
2. Direct discharge to lagoons. This is most commonly used by industry.
3. Anaerobic digestion followed by pipeline transportation to the ocean or land reclamation areas. This is by far the least expensive method.
4. Digestion followed by barging for disposal at sea is economical. This method is most commonly used by near coastal cities, with access to the ocean.

Mechanical dewatering of sludge, incineration, and land disposal of sludge are increasing in popularity.

Costs

<u>Process</u>	<u>Costs</u>	<u>Source</u>
1. Digestion + Sand Bed Dewatering	\$25/ton	Burd ²⁹
2. Pipelining to Sea or Land Disposal	\$3-7/ton	Cleveland ³⁰
3. Barging to Sea	\$9/ton	New York ³¹
4. Digestion and Reclamation of Farm Land	\$15/ton	Chicago ³²
5. Digestion and Reclamation of Strip Mine	\$16/ton	"
6. Drying and Selling as Fertilizer (net)	\$45/ton	"
7. Digesting and Lagooning	\$49/ton	"
8. Wet Air Oxidation (Zimpro)	\$50/ton	"
9. Dewatering and Incineration	\$57/ton	"

SUMMARY AND CONCLUSIONS

In any sludge disposal problem, it is essential to consider the character of the sludge, the availability of land, the suitability of the sludge for disposal to a waterway, the possible use of the sludge as a fertilizer, and capital and operating costs.

This paper has attempted to present the presently available methods and their costs and those which are being researched for disposal of sludge solids. Treatment plant space, nuisance problems, economics, and health are involved.

BIBLIOGRAPHY

1. Gale, R. S., "Some Aspects of the Mechanical Dewatering of Sewage Sludges," Filtration and Separation, March/April 1968, pp. 1-12.
2. Keefer, C. E., "Sewage Treatment Works," McGraw-Hill Book Co., Inc. New York, 1940.
3. Fair, G. M., and Imhoff, K., "Sewage Treatment," John Wiley and Sons, Inc., New York, 2nd edition, 1965.
4. Babbitt, H. E., "Sewerage and Sewage Treatment," John Wiley and Sons, Inc., New York, 7th edition, 1953.
5. McCabe, J., and Eckenfelder, W. W., "Advances in Biological Waste Treatment," Pergamon Press, 1963.
6. Stanley, William E., Personal Communication, Washington University, St. Louis, Mo., 1967.
7. Malina, J. F., Jr., "Aerobic Sludge Stabilization," in Manual of Treatment Processes, Vol. I, by W. W. Eckenfelder, Jr., Environmental Science Services Corp.
8. McCarty, P. L., "Anaerobic Waste Treatment Fundamentals--Part One--Chemistry and Microbiology," Public Works 95 (9), 107-112 (Sep. 1964).
9. Hart, S. A., "Solid Waste Management/Composting: European Activity and American Potential," Public Health Service Publ. No. 1826, U. S. Govt., Printing Office, Washington, D. C., 1968, 40 pp.
10. Coackley, P., and Jones, B. R. S., "Vacuum Sludge Filtration-I. Interpretation of Results by the Concept of Specific Resistance," Sewage and Industrial Wastes, Vol. 28, No. 8, pp 963-975, August, 1956.
11. Schepman, B. A. and Cornell, C. F., "Fundamental Operating Variables in Sewage Sludge Filtration," Sewage and Industrial Wastes, Vol. 28, No. 12, December 1956.
12. FWPCA Contract No. 14-12-188 with Foster D. Snell, Inc., on "Sulfur Dioxide Catalyzed Sludge Hydrolysis."
13. Greenfield, C., "The Carver-Greenfield Process for Waste Reclamation," presented at the Water Pollution Control Federation Conference, Kansas City, Missouri, Sept. 29, 1966.
14. Bouthilet, R. J. and Dean, R. B. "Hydrolysis of Activated Sludge." Pres. 5th International Water Pollution Research Conf., San Francisco, Calif., 7/31/70. Preprints published by Conference. All papers to be assembled and published by Pergamon Press, 1971.

15. Doe, P. W., Benn, D., and Bays, L. R., "The Disposal of Washwater Sludge by Freezing," Journal Institute of Water Engineers, 19 (4), 251-291 (June 1965).
16. Katz, W. J., and Mason, D. G., "Freezing Method for Conditioning Activated Sludge," Proc. 16th Southern Water Resources and Pollution Control Conference, Duke University, 1967.
17. Farrell, J. B., Smith, J. E., Jr., Grossman, E. III, Grant, O. L., and Dean, R. B., "Natural Freezing for Dewatering of Aluminum Hydroxide Sludges," presented at the AWWA Washington Conference, June 25, 1970.
18. Vater, W., "European Practices in Sludge Dewatering and Disposal," in Advances in Water Quality by Gloyna and Eckenfelder, 1969.
19. Teletzke, G. H., "Wet Air Oxidation," Chem. Eng. Prog. 60 (1), 33-38 (1964).
20. Evans, S. C., Roberts, F. W., "Heat Treatment of Sewage Sludge," The Surveyor, 9-12 (Jan. 3, 1947).
21. Isaac, P. C., "Sludge Drying," Effluent and Water Treatment Journal 2 (4), 196-198 (April 1965).
22. Albertson, O. E., and Ginde, E. E., Jr., "Centrifugation of Waste Sludges," Journal Water Pollution Control Federation 41(4), 607 (April 1969).
23. Katz, W. J., Geinopolis, A., "Sludge Thickening by Dissolved Air Flotation," presented at 13th Annual Wastes Engineering Conference, University of Minnesota, Dec. 10, 1966.
24. Sparr, A. E., and Gippi, V., "Gravity Thickeners for Activated Sludge," presented at 41st Annual Conference of Water Pollution Control Federation, 1968.
25. FWPCA Grant to Chicago Metropolitan Sanitary District, "Land Utilization."
26. FWPCA Grant to Seattle Metro, WPRD #180-01(R1)68, "Park Development."
27. FWPCA Contract 14-12-30 to Rand Development Corp., on "Pipeline Transport."
28. Sebastian, F. P., and Cardinal, P. J., "Solid Waste Disposal," Chem. Eng. 75, 112-117 (Oct. 14, 1968).
29. Burd, R. S., "A Study of Sludge Handling and Disposal," FWPCA Publication No. WP-20-4, May 1968.

30. Wirts, J. J., "Pipeline Transportation and Disposal of Digested Sludge," Sewage and Industrial Wastes 28(2), 121-131 (Feb. 1965).
31. Scanlon, A. J., "Utilization of Sewage Sludge from the Product of Topsoil," Sewage and Industrial Wastes 29(8), 944-950 (Aug. 1957).
32. Dalton, F. E., Stein, J. E., and Lynam, B. T., "Land Reclamation-- A Complete Solution of the Solid Disposal Problem," Journal Water Pollution Control Federation 40(5), 789 (May 1968).

ACKNOWLEDGEMENTS

The author would like to express his appreciation to Dr. J. B. Farrell who assisted in the revision of this paper and to both Drs. R. B. Dean and J. B. Farrell for their advice on the research work reported in this paper. Particular appreciation is also expressed to Messrs. S. W. Hathaway, O. L. Grant, and H. E. Thomas of the Ultimate Disposal Research Program, FWQA, for their efforts in obtaining the data to make this paper possible.